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AUTHOR Hinkle, Dennis; Houston, Charles A.
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ABSTRACT

The purpose of this study was to present and evaluate Bayesian-type models for estimating probabilities of program completion and for predicting first quarter grade point averages of community college students entering certain allied health fields. Two Bayesian models were tested. Bayesian Model 1--Estimating Probabilities of Program Completion--was developed from discrete cases of Bayes' formula with counselors' inputs as a priori probabilities and posterior probabilities of graduate status of the discriminant analysis function as likelihoods. The a priori probabilities and likelihood probabilities were combined in Bayes' Theorem to produce posterior probabilities of successful program completion. Bayesian Model 2--Predicting First Quarter Grade Point Averages--which was an application and specialization of the Bayesian linear model developed by Lindley and Smith, involved the assumption of homogeneity of regression coefficients (but not intercepts) across groups. The efficiencies for both Bayesian models were compared and evaluated in terms of two counselor-selection models and two classical statistical models with the results showing that Bayesian Model 1 was most efficient in selecting successful students while no significant difference in efficiency was found for Bayesian Model 2 as compared to a classical statistical model. (Author/JDS)

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A COMPARATIVE STUDY OF THE EFFECTIVENESS OF TWO BAYESIAN MODELS FOR PREDICTING THE ACADEMIC SUCCESSES OF SELECTED ALLIED HEALTH STUDENTS ENROLLED IN THE COMPREHENSIVE COMMUNITY COLLEGE

BY

DENNIS HINKLE
VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY
BLACKSBURG, VIRGINIA

AND

CHARLES A. HOUSTON
VIRGINIA WESTERN COMMUNITY COLLEGE
ROANOKE, VIRGINIA

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A COMPARATIVE STUDY OF THE EFFECTIVENESS OF TWO BAYESIAN MODELS FOR PREDICTING THE ACADEMIC SUCCESSES OF SELECTED ALLIED HEALTH STUDENTS ENROLLED IN THE COMPREHENSIVE COMMUNITY COLLEGE

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Charles Aiken Houston, Jr.

(ABSTRACT)

Because of high enrollment demands, limited instructional spaces, and the high cost of programs, many community colleges have been forced to place stringent admission requirements in the guidance and selection of certain allied health curricula such as Dental Assistant, Mental Health, Nursing, and Radiology. In this guidance-selection environment in which there were more candidates than vacancies, methods and/or procedures must be established that discern the "best" applicants. Since neither the classical statistical models which utilize correlations, regression, discriminate analysis, etc. nor the counselor-selection models have typically utilized all the information regarding a student, the need for more efficient and effective guidance-selection models was indicated. In this context Bayesian-type models have been proposed that can utilize the strengths of both the classical statistical models and the counselor-selection models.

The purpose of the study was to present and evaluate Bayesian-type models for estimating probabilities of program completion and predicting first quarter grade point average (GPA). Bayesian Model 1 - Estimating Probabilities of Program Completion was developed from the

discrete case of Bayes' formula with counselors' inputs as a priori probabilities and posterior probabilities of graduate status of the discriminant analysis function as likelihoods. The a priori probabilities and likelihood probabilities were combined in Bayes' Theorem to produce posterior probabilities of successful program completion. Bayesian Model 2 -- Predicting First-Quarter GPA's which was an application and specialization of the Bayesian linear model developed by Lindley and Smith (1972) involved the assumption of homogeneity of regression coefficients (but not intercepts) across groups. The efficiencies of the Bayesian-type models were compared and evaluated in terms of two counselor selection models and two classical statistical models.

Although inspection by curriculum and by individual students indicated that all three program completion models were appropriate in specific cases, an analysis of ranking efficiencies using the Friedman (1937) test rejected the hypothesis of identical treatments. Further analyses using multiple comparisons aspects proposed by Anderson (1959) indicated that there were statistically significant linear comparison differences among the models with the Bayesian Model 1 ranking as the most efficient model. An analysis of the three GPA models using an analysis of variance test contradicted the hypothesis that the three treatment effects were equal at the .01-level with Tukey's Test for differences of average absolute-errors confirming that the Bayesian Model 2 and the Classical Statistical Model 2 were more efficient than the Counselor Model 2. The results of the study supported several recommendations for further study.

INTRODUCTION*

Because of high enrollment demands, limited instructional spaces, and the high cost of programs, many community colleges have been forced to place stringent admission requirements in the guidance and selection of students for certain allied health curricula such as Dental Assistant, Mental Health Technology, Nursing, and Radiology. Since recent research studies (A.W. Astin, 1975; H.S. Astin, 1970; Summerskill, 1962; Trent and Medsker, 1967) have reported withdrawal rates of 50 percent and higher for students entering community college programs, a need for more efficient and effective guidance-selection models was indicated. Models that accurately predicted first-quarter GPA's and efficiently estimates the probability of successful program completion would benefit both the college and the students that enroll in these curricula.

The purpose of the study was to present and evaluate Bayesian-type models for estimating probabilities of program completion and predicting first-quarter GPA's for students entering four allied health curricula of the comprehensive community college. Bayesian Model 1 -- Estimating Probabilities of Program-Completion was developed from the discrete case of Bayes' formula as presented by Powers (1973, p. 4). Powers' methodology which utilized counselor/faculty advisors' inputs as a priori probabilities was extended by using posterior probabilities of graduate status of the discriminant analysis function as likelihoods.

*This study summarizes a dissertation submitted by the second author in partial fulfillment of the requirements for the degree of the Doctor of Philosophy in Educational Research and Evaluation, Virginia Polytechnic Institute and State University, April 1976, Blacksburg, Virginia.

The a priori probabilities and likelihood probabilities were combined in Bayes' Theorem to produce posterior probabilities of successful program completion. Bayesian Model 2 -- Predicting First-Quarter GPA's utilized a computer program developed by Kazuo Shigemasu (1975). This model which was an application and specialization of the Bayesian linear model developed by Lindley and Smith (1972) involved the assumption of homogeneity of regression coefficients (but not intercepts) across groups. This methodology (first proposed by Novick, Jackson, Thayer, and Cole, 1971) comparing GPA predictions across different schools with similar programs was adjusted in terms of comparing similar programs within one college (i.e. the m-groups were now different programs instead of different schools). The efficiencies of the Bayesian-type models were compared and evaluated in terms of two counselor selection models and two classical statistical models.

Although a review of the literature dealing with the prediction of academic success revealed a wealth of materials concerning the prognosis of college and university success, there have been few studies that dealt with the problem in an experimental fashion. In general, prediction studies have been ex post facto research in which the independent variable or variables have already occurred and the researcher starts with the observation of a dependent variable or variables. Little or no efforts have been directed toward cross validation studies which predict the academic success of the next class and/or evaluate the efficiency of the prediction models in terms of the new class. The literature review also noted that little effort has been directed toward developing and evaluating multiple prediction procedures. Therefore, the purpose of the present study was to present and evaluate multiple

prediction procedures in a quasi-experimental fashion by using data for new allied health classes first enrolled for Fall 1975.

The design of the study required that three program-completion models and three GPA prediction models be constructed from data discerned from previous students enrolled from the Fall of 1972 through the Fall of 1974. These models were used to predict first-quarter GPA and probabilities of program completion for students first enrolled for Fall 1975. The efficiencies of the models were compared by examining predicted GPA in terms of actual first-quarter GPA and estimates of probabilities of program completion in terms of actual graduate-nongraduate status (enrolled or withdrawn) for Spring 1976.

The total sample of the study consisted of 374 students who were enrolled in the curricula of Dental Assisting, Mental Health Technology, Nursing, and Radiology. Data for students enrolled from Fall 1972, 1973, and 1974 were used to develop statistical equations (discussed below) necessary for developing the six prediction models for students entering in the Fall 1975.

The predictor (independent) variables consisted of selected academic variables discerned by examining both previous research results and present theories concerning academic achievement with additional recommendations from allied health counselors, faculty, and administrators. The criterion (dependent) variables consisted of (1) first-quarter GPA and (2) graduate/nongraduate status.

Several statistical methods were employed in developing the six prediction models. These methods were summarized as follows:

Program-Completion Models	Statistical Methods
Bayesian Model 1 -- Estimating Probabilities of Program-Completion	Application of Bayes' formula using counselor's assignment of probability of successful programs completion as a priori probability and discriminate score of probability of graduate classification as likelihood.
Counselor Model 1 -- Estimating Probabilities of Program - Completion	Counselor's assignment of probability of successful program completion.
Classical Statistical Model 1 -- Estimating Probabilities of Program-Completion	Discriminant analysis for graduate/nongraduate group membership using the discriminate score to estimate the students' success in completing the specific allied health curriculum.
GPA Prediction Models	
Bayesian Model 2 -- Predicting First Quarter GPA's	Bayesian M-group Regression Analysis with Identical Regression Coefficients
Counselor Model 2 -- Predicting First Quarter GPA's	Counselor's assignment of first-quarter GPA
Classical Statistical Method 2 -- Predicting First-Quarter GPA's	Forward stepwise multiple regression using SPSS REGR

Several statistical methods were employed in comparing and evaluating the effectiveness of prediction models. The program completion models were evaluated by comparing the mean absolute-errors and the mean squared-errors by both individual curriculum and by combined curricula. The Friedman test was used to evaluate the three models by ranking the predicted probabilities in terms of actual status. In the case that the null hypothesis of equal likely rankings within a block (student) was rejected, multiple comparisons were examined in terms of tests presented by Anderson (1959) for rank data.

The three GPA prediction models were evaluated by examining the absolute-error-loss function, squared -error-loss function, and using the analysis of variance (F-test) of predicted and actual GPA differences for a single-factor experiment having repeated measures on the same element (Winter, 1962, pp. 105-124). The efficiencies of the models were compared and evaluated in terms of the average absolute-error-loss and average squared-error-loss by both individual curricula and combined curricula.

The study was limited in that certain restrictions were placed on the six prediction models. This fact was especially true for the Classical Statistical Model 1 which employed multiple regression in the traditional sense because counselors' evaluations of students first enrolled Fall 1972, 1973, and 1974 were unavailable to be used as independent variables in developing the GPA prediction equation. The study was also limited by certain time factors which required that the criterion of graduate/non-graduate status for students first enrolled Fall 1975 to be determined in terms of enrolled/not enrolled for Spring 1976. Other limitations concerned missing data of high school rank and School and College Ability Test (SCATS) scores.

CONCLUSIONS

The results of the study indicated that there were little differences in the prediction efficiencies of the three models in reducing the weighted average absolute-errors of the four allied health curricula. The analysis of rank order efficiencies of the three models indicated that the weighted average absolute-error differences between the actual status (1 - graduate and 0 - non-graduate) and the predicted status for

the 93 students in the four allied health curricula were as follows: (1) Bayesian Model 1 (0.34), (2) Counselor Model 1 (0.35), and (3) Classical Statistical Model 1 (0.40). Further descriptive analysis of the rank order efficiences of the three models indicated that the weighted average squared-error differences between the actual status (1 - graduate and 0 - nongraduate) and the predicted status for the 93 students in the four allied health curricula were as follows: (1) Classical Statistical Model 1 and Counselor Model 1 tied (0.22) and (2) Bayesian Model 1 (0.24). Although inspection by curriculum and by individual students indicated that all three models were appropriate in specific cases, an analysis of ranking efficiencies of the three models using the Friedman (1937) test rejected the hypothesis of identical treatment effects at the .05-level. Further analyses using multiple comparisons aspects proposed by Anderson (1959) revealed the following:

1. There were no statistically significant differences between the rankings assigned to Counselor Model 1.

2. There were statistically significant linear comparison differences among models for rank 1. Inspection of the models receiving rank 1 clearly indicated that the Bayesian Model 1 (56 rank 1) exceeded the rank 1 of either the Classical Statistical Model 1 (25 rank 1) or the Counselor Model 1 (12 rank 1).

3. There were statistically significant differences between linear rankings for Bayesian Model and Classical Statistical Model 1. Inspection of the data clearly supported the hypothesis that the Bayesian Model 1 was the most efficient model in selecting successful allied health students who would complete their programs of study.

A descriptive analysis of the three GPA models indicated there were little differences in the prediction efficiencies of the Bayesian and classical statistical models in reducing the weighted average absolute-errors for the 93 students enrolled in the four allied health

curricula. Counselor Model 2 was less efficient than either the Bayesian or classical statistical models. The rank order efficiencies of the three models indicated that the weighted average absolute-error differences between actual first-quarter GPA and predicted GPA were as follows: (1) Bayesian Model 2 (0.719), (2) Classical Statistical Model 2 (0.723), and (3) Counselor Model 2 (0.829). An analysis of variance of mean differences of absolute-errors using a single-factor design having repeated measures on the same elements $F(2,184) = 5.774$ contradicted the hypothesis that the three treatment effects were equal at the .01 level with Tukey's Test for differences of average absolute-errors confirming that the mean absolute-errors of the Counselor Model 2 differs from the means of both the Bayesian Model 2 and the Classical Statistical Model 2. Further descriptive analysis of weighted mean averages of predicted and actual GPA differences of squared-error found little differences in the predicted efficiencies of the three models. A rank order of most efficient to least efficient for the weighted average squared-errors was as follows: (1) Bayesian Model 2 (1.206), (2) Classical Statistical Model 2 (1.233), and (3) Counselor Model 2 (1.368). An analysis of variance of mean differences of squared-errors using a single-factor design having repeated measures on the same elements failed to reject the hypothesis that the squared-error differences were different at the .05 level for the three GPA prediction models.

Because several investigators (Nicholson, 1970; Heist, 1968; Savicki and others, 1970) have noted that dropouts were not different from successful persisters on predicted GPA, the study concluded that there was a greater need to learn more about the prediction of graduation from college as a criterion of college success rather than college GPA.

This fact was especially true for the allied health curricula because in most cases graduation itself was the key to entering the occupational fields. In order to provide the greatest information to counselors and students concerning an estimate of their predicted graduate/nongraduate status, the need for a multiple comparison selection system was established by the results of the present study. These results indicated that the counselor and possibly the student could benefit from examining the prediction estimates provided by the different program-completion models. Because graduation was partially a function of GPA, the study concluded that GPA's should be viewed as necessary but not sufficient conditions for future academic successes. Therefore, it was necessary to examine predicted GPA's in terms of predicted program-completion probabilities.

RECOMMENDATIONS

The results of the study supported several recommendations for further study. First and foremost, the Bayesian-type procedures produced results which indicated that they are deserving of further investigating. Since the major problem in Bayesian inference has been that of quantifying a priori information, further studies were recommended in terms of establishing methodologies that assist counselors and faculty advisors in quantifying and understanding the processes of estimating and assigning probabilities for program-completion and predicting first-quarter GPA's. Additional investigations should discern topics such as: How did these counselors actually make the decisions for assigning the program-completion estimates and the GPA predictions? Why were the models very accurate in the case of student 5 and totally inaccurate in the case of student 10? Were there characteristics that can be identified which would discriminate

between students who were accurately classified and students who were inaccurately classified?

In terms of the GPA models, it was certainly obvious that additional variables should be added to the Classical Statistical Model 2 and the Bayesian Model 2. It was recommended that additional academic variables with biographical, demographical, and attitude/opinion variables be added to the study. The possibility of using certain types of factor analyses of the variables and using the factor scores as independent variables should be discerned. The use of additional academic and nonacademic variables for the program-completion models should also be investigated. In addition,studies that jointly examine GPA and problem-completion prediction models and their relationship should be examined.

Although the three program-completion and GPA models represented extremes on a continum, it was recommended that the following additional models be proposed and investigated in terms of multiple comparison studies:

1. Both the Classical Statistical Model 2 -- Predicting First-Quarter GPA and the Bayesian Model 2 -- Predicting First-Quarter GPA should be extended with the inputs of certain counselors' evaluations as independent variables.

2. The use of dummy independent variables in coding the four allied health programs for the Classical Statistical Model 2 -- Predicting First-Quarter GPA should be considered in future studies.

3. The use of certain nonlinear transformations should be considered in developing future GPA prediction models.

4. Novick's original M-group regression program should be considered in future studies.

5. Theoretical work should be extended to incorporate a priori beliefs of counselors into the Bayesian M-group regression procedures.

In addition many cross validation studies should be examined in order to establish the validity of impressive correlation coefficients that have been developed by ex post facto research.

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